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<td>Matsubara, Takako / Uehara, Yoshinobu / Yamamoto, Takuo / Miki, Akinori</td>
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<td>掲載誌・巻号・ページ</td>
<td>Bulletin of health sciences Kobe,16:63-76</td>
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<tr>
<td>刊行日</td>
<td>2000-12-27</td>
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<tr>
<td>資源タイプ</td>
<td>Departmental Bulletin Paper / 紀要論文</td>
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<tr>
<td>版区分</td>
<td>publisher</td>
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<td>JaLCDOI</td>
<td>10.24546/00098326</td>
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<td>URL</td>
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PDF issue: 2019-07-24
Macroscopic Observations on Human Lower Leg Muscles

Takako Matsubara¹, Yoshinobu Uehara², Takuo Yamamoto³, and Akinori Miki¹

Using 16 human lower legs from 8 cadavers, we macroscopically examined the origin and insertion, distribution of intramuscular tendons and arrangement of muscle fibers in the lower leg muscles. These muscles were widely covered with the firm fascias that were continuous with the tendons of origin or insertion, and contained one or more intramuscular tendons that were also continuous with the tendons of origin or insertion. Muscle fibers in these muscles arranged unipennately, bipennately or radially among the intramuscular tendons and fascias. According to arrange of the muscle fibers, the proximal two third of the tibialis anterior can be regarded as the radiate type, and the distal one third, as the unipennate type. The proximal half of the extensor digitorum longus can be regarded as the radiate type and the distal half, as the unipennate type. The proximal half of the peroneus longus and brevis belong to the bipennate type and the distal half, to the unipennate type. We found also that in the extensor digitorum longus, medial head of the gastrocnemius and soleus, the tendon of origin or insertion twisted spirally. It should be emphasized that distribution of the intramuscular tendons and arrangement of the muscle fibers are very important for the palpation and stretching of muscles in the physical therapy.

Key Words: Human lower leg muscles, Macroscopic anatomy, Intramuscular tendons, Arrangement of the muscle fibers.

Introduction

Previously, we macroscopically examined the origin and insertion of muscle fibers in the human gluteus maximus, and reported that the gluteus maximus connected with several muscles through tendon, fascia and ligament (muscle connection).¹ These muscle connections were reported in almost all muscles.² We also examined the arrangement of the muscle fibers in the human gluteus maximus, and found that they could be divided into 3 groups, i.e., superficial, upper deep and lower deep fiber groups.³ Since each group has different insertion, it is suggested that they are involved in different functions. The origin, insertion, fiber arrangement and muscle connection are considered to be very important not only for muscle function, but also for stretching and myotherapy in the physical therapy.
Muscles in the lower leg are usually divided into 4 groups, i.e., the extensor (tibialis anterior, extensor digitorum longus and extensor hallucis longus), peroneal (peroneus longus and peroneus brevis), superficial flexor (gastrocnemius and soleus), and deep flexor (tibialis posterior, flexor hallucis longus and flexor digitorum longus) muscle groups. Of these, the extensor, peroneal and superficial flexor muscle groups are palpable from the surface, and very important for physical assessment and therapy. Thus, in the present study, we macroscopically examined these items in these muscle groups of the human lower leg.

Subjects and Methods

In the present study, we used 16 lower legs from 4 male and 4 female cadavers (average death age: 81.0). The skin of the lower leg was removed, and the crural fascia, intermuscular septum and connective tissues were carefully eliminated to separate each muscle. The origin, insertion and muscle connection of each muscle were macroscopically examined. Thereafter, these muscles were transversely and longitudinally cut with a surgical knife to examine the distribution of intramuscular tendons and arrangement of muscle fibers.

Results

The extensor muscle group
Tibialis anterior
In all cases, the tibialis anterior originated from the upper half of the lateral surface of the tibia, upper two third of the anterior surface of the crural interosseal membrane and crural fascia. A tendon of insertion of this muscle began at level of the inferior one third of the lower leg, run in parallel with the medial margin of the tibia and attached to the plantal surface of the medial cuneiform bone and the first metatarsal bone. Since the muscle fibers constituting the anterior surface appeared to run in parallel with the long axis of the muscle, this muscle is regarded as fusiform type (Fig. 1A). In cross sections at the level of the head and belly, the tibialis anterior was triangle in form and contained a tabular intramuscular tendon at the center of the belly (Figs. 2A, B). In longitudinal sections, the intramuscular tendon extended proximally near to the origin site, and continued distally with the terminal tendon (Fig. 2C). At the head and belly levels, short oblique muscle fibers radially attached to the intramuscular tendon (Fig. 2D). On the other hand, at the lower level, short oblique muscle fibers attached unipennately to the tendon of insertion (Figs. 1B, C). Thus, according to the arrangement of the muscle fibers, the proximal two third of the tibialis anterior can be regarded as radiate type, and the lower one third, as unipennete type.

Extensor digitorum longus
The extensor digitorum longus originated from the lateral surface of the proximal end of the tibia, anterior margin of the fibula, crural interosseous membrane and crural fascia, and inserted into the second to fifth dorsal digitorum aponeurosis. At the lower one third of the lower leg level, the tendon of insertion located medially, and the oblique muscle fibers unipennately attached to the tendon (Figs. 3A, B). As the muscle extended proximally, the tendon
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Figure 1. A: Anterior aspect of the tibialis anterior (TA). The superior one third of the muscle is covered with the fascia. The tendon of insertion (TI) begins at the level of the inferior one third of the lower leg. B and C: At the lower level, short oblique muscle fibers (asterisk) attach unipennately to the TI. TT: tibial tuberosity; LM: lateral malleolus.

Figure 2. A and B: Cross sections of the tibialis anterior at the belly level. The muscle is triangle in form and contains a tabular intramuscular tendon (inMT) at the center. C and D: Longitudinal sections of the belly and head. Short oblique muscle fibers (asterisk) radially attach to the inMT. TA: tibialis anterior.
was twisted spirally (Figs. 3D, 4A, B). Thus, near the proximal end of this muscle, the tendon located deeper to the muscle fibers. In the proximal half of the muscle, muscle fibers arising from the tibia, fibula, crural interosseous membrane and crural fascia radially inserted into the tendon. Accordingly, the proximal half of this muscle can be regarded as radiate type, and the distal half, as unipennate type.

**Extensor hallucis longus**

The extensor hallucis longus originated from the medial surface of the fibula and crural interosseous membrane. The tendon of insertion of this muscle began at the level of the inferior two thirds of the lower leg (Fig. 3B), run in parallel with the tendon of the tibialis anterior, and inserted into the first dorsal digitorum apponeurosis. The tendon of insertion run along the medial edge of this muscle (Figs. 4A, C), and the oblique muscle fibers unipennately attached to the tendon (Fig. 3D). The extensor hallucis longus and extensor digitorum longus connected with each other through muscle connection (Fig. 3C). Accordingly, this muscle can be regarded as unipennate type.

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**Figure 3.** A: Antero-lateral aspect of the lower leg. The extensor digitorum longus (EDL) runs downward along the posterior margin of the tibialis anterior (TA). LM: lateral malleolus. B: The antero-lateral aspect of the distal part of the lower leg. At the lower level, the extensor hallucis longus (EHL) can be observed between the TA and EDL. The tendon of insertion of the EDL and EHL locate medially in each muscle. C and D: The EHL and EDL are manually separated from each other. Oblique muscle fibers of the EHL and EDL (asterisks) unipennately attach to the tendon of insertion. As the EDL extends proximally, the tendon twists spirally (TT and ++++), and muscle fibers radially attach to the tendon. xxx: muscle connection.
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Figure 4. Transverse sections at the bellies of the extensor digitorum longus (EDL) and extensor hallucis longus (EHL). The tendon of the EDL twists spirally (TT and +++) as the muscle extends proximally (A to C), and becomes to locates deeper in the muscle. Short oblique muscle fibers radially attach to the tendon. The extensor hallucis longus (EHL) locates anteromedial to the EDL, and muscle fibers attached to the tendon of insertion (TI).

The peroneal muscle group

Peroneus longus
The peroneus longus originated from the lateral condyle of the tibia, head of the fibula, upper one third of the lateral margin of the fibula, crural fascia, intermuscular septum, and tibiofibular joint capsule. The tendon of insertion began at the middle level of the lower leg (Fig. 5A), run downward and attached to the plantar surface of the medial cuneiform bone and the first metatarsal bone. At the distal half of the lower leg level, the oblique muscle fibers unipennately attached to the tendon (Figs. 5B, C). In cross sections at the level of the belly, the muscle contained a tubular intramuscular tendon at the center of the muscle (Fig. 6B). While at the level of the head, the tendon became oval in shape (Fig. 6A). In longitudinal sections, short oblique muscle fibers attached bipennately to the tendon in the proximal half of the muscle (Fig. 6C). Judging from these findings, the proximal half of this muscle can be regarded as bipennate type, and the distal half, as unipennate type.

Peroneus brevis
The peroneus brevis originated from the lateral surface of the fibula, and run down beneath the peroneus longus. The tendon of insertion of this muscle began at the middle level of the lower leg (Figs. 7A, B), and attached to the tuberosity of the fifth metatarsal bone. At the distal half levels of the lower leg, oblique muscle fibers unipennately attached to the tendon (Figs. 7E, F). While at the head and belly levels, a thin membranous tendon was observed at the center of the muscle, and short oblique muscle fibers bipennately attached to the tendon (Figs. 7C, D). Accordingly, the proximal half the muscle can be regarded as bipennate, and the distal half, as unipennate type.

The superficial flexor muscle group

Gastrocnemius
The medial and lateral heads of the
gastrocnemius originated from the medial and lateral condyl of the femur, respectively (Figs. 8A-D). The tendon of insertion began at the middle level of the lower leg as the Achilles tendon that run downward and attached to the calcaneal tuberosity. As the muscle extended proximally, the medial head twisted spirally, and the tendon of origin deviated medially (Figs. 9B-D). In the lateral head, the tendon of origin gradually became slender and shifted laterally (Fig. 9A). In longitudinal section, the muscle fibers originating from the anterior fascia unipennately attach to posterior fascia (Figs. 10B, C). In transverse section, several intramuscular fasciae were seen among the bundles of muscle fibers (Fig. 10A). Accordingly, the gastrocnemius can be regarded as unipennate type.

**Soleus**

The soleus originated from the soleus line in the tibia, medial margin of the fibula, and tendinous arch of the soleus. The medial three fourth of the anterior surface (Fig. 11A) and both medial and lateral one third of the posterior surface (Fig. 11B) were covered with the fascia that was continuous with the Achilles tendon. When the posterior fascia was removed, two tendons being continuous with the tendon of

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Figure 5. Lateral aspect of the lower leg. A: The tendon of insertion (TI) of the peroneus longus (PL) begins at the middle level of the lower leg. In the distal half portion of the PL, oblique muscle fibers unipennately attach to the TI. B and C: When the PL is turned posteriorly, the peroneus brevis (PB) becomes visible beneath the PL. In the PL and PB, short oblique muscle fibers unipennately attach to the TI. LM: lateral malleolus.
origin run downward to the distal one third of the lower leg (Fig. 11C). In the head and belly, short muscle fibers run obliquely among the anterior and posterior fasciae and intramuscular tendons. But in the caudal portion, oblique muscle fibers arising from the intramuscular tendons and fasciae attached directly to the Achilles tendon. In longitudinal sections, one other membranous tendon being continuous with the tendon of origin was observed (Fig. 11D). Oblique muscle fibers arising from the tendon attached to the fasciae covering the anterior and posterior surfaces of the muscle. On the basis of these findings, the soleus can be regarded as radiate type muscle.

Discussion

The tibialis anterior, peroneus brevis

Figure 6. Transverse and longitudinal sections of the peroneus longus (PL). A and B: In transverse sections at the head and belly levels, the intramuscular tendon (inMT) is rod and tabular in shape, respectively. C: In longitudinal section, the inMT runs centrally along the long axis of the muscle, and short oblique muscle fibers (asterisk) bipennately attach to the inMT.
and soleus contained one or more longitudinally oriented long intramuscular tendons that were continuous with the tendons of origin or insertion. The

Figure 7. A: Since the peroneus brevis (PB) runs downward beneath the peroneus longus (PL), the PB can be observed from the surface only near the ankle joint. B and C: The tendon of insertion (TI) of the PB begins at the middle level of the PB. D: At the levels of the belly and head, a membranous intramuscular tendon (inMT) is observed at the center, and short oblique muscle fibers attach bipennately to the inMT. E and F: At the lower levels, short oblique muscle fibers (asterisks) attach unipennately to the tendon of insertion (TI).
surface of these muscles was covered with a widely spread firm fascia, that were also continuous with the tendons of origin or insertion. In these musc-

**Figure 8.** Posterior aspect of the gastrocnemius. A: The medial and lateral heads (MH and LH) of the gastrocnemius originate from the medial and lateral condyles of the femur (MC and LC), respectively, and continue distally with the Achilles tendon. B, C and D: Since the medial head of this muscle twists medially, the tendon of origin (TO) becomes to locate medially and attaches to the medial condyle (MC). On the other hand, in the lateral head of this muscle, the tendon of origin (TO) gradually becomes slender, as the muscle extends proximally.
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les, individual muscle fibers were relatively short in comparison with the entire length of the muscle, and attached unipennately, bipennately or

Figure 9. A: A cross section at the proximal end of the lateral head of the gastrocnemius. The tendon of origin (TO) becomes very thin and locates in lateral portion of the head. B: The medial head is cut at the origin. Since the head twists medially, the tendon of origin (TO) extends spirally toward the origin (asterisks). C and D: The lateral (LH) and medial heads (MH) are cut and turned distally. Note that the medial head (asterisks) twists medially and becomes very thick.
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radially to these tendons and fasciae. It is said that though the muscles composed of short muscle fibers can not contract faster than those of long muscle fibers, they can produce much more contraction power.\textsuperscript{4,6} Thus, these

Figure 10. A: Cross sections of the gastrocnemius at the belly level. The intramuscular fasciae (inMF) divide the muscle belly into several parts. B and C: The fascia covering the anterior surface of the muscle is longitudinally cut. The muscle fibers (asterisks) originating from the anterior fascia unipennately attach to posterior fascia. Intramuscular fasciae are seen among the muscle fibers.
muscles might be suitable for the lower leg, because the lower leg should sustain the whole body weight against the gravity. According to the arrangement of muscle fibers, the skeletal muscles have

Figure 11. A: Posterior aspect of the soleus. The medial three forth of the muscle is covered with the fascia that continues distally with the Achilles tendon. B: The medial and lateral one third of the posterior surface are also covered with the fascia. C: When the posterior fascia is removed, two tendons extending from the tendon of origin run downward. The short muscle fibers (asterisks) run obliquely among the tendons. D: At the belly level, short oblique muscle fibers (+++) originate bipennately from the intramuscular tendon (inMT) of ori-
been classified into several types, such as fusiform, unipennate and bipennate types. In the fusiform type muscles, long muscle fibers run in parallel with the long axis of the muscle. In the unipennate type, a longitudinal tendon runs unilaterally along the margin of the muscle, and short oblique muscle fibers attach to the tendon unilaterally. In the bipennate type muscles, a longitudinal tendon runs centrally along the axis of the muscle, and short oblique muscle fibers attach to the tendon bilaterally. In the present study, we found that in some lower leg muscles, one or more longitudinal tendons run within the muscle, and short oblique muscle fibers attached radially to these tendons. The radial arrangement of muscle fibers was also reported in some muscle (brachioradialis, extensors and flexors of digit, tibialis anterior and plantaris). In this study, muscles exhibiting the radial arrangement of muscle fibers are named as radiate type. According to our observation, the extensor hallucis longus and gastrocnemius belong to the unipennate type, and the soleus, to the radiate type. But in some muscles, the arrangement of the muscle fibers was different between parts. The proximal two third of the tibialis anterior can be regarded as the radiate type, and the distal one third, as the unipennate type. The proximal half of the extensor digitorum longus can be regarded as the radiate type and the distal half, as the unipennate type. The proximal half of the peroneus longus and brevis belong to the bipennate type and the distal half, to the unipennate type. The arrangement of muscle fibers in the skeletal muscles is very important for understanding the muscular function. In the extensor digitorum longus, medial head of the gastrocnemius and soleus, the tendon of origin twisted spirally, and run longitudinally within the belly and head. These spirally twisted tendons were also reported by Morimoto. It has been said that this twisting structure of tendon is very effective to absorb stretching tension and to prevent the tendon from rupturing. It is also possible that with this spiral structure, much more muscle fibers can attach to the tendon in a narrow space.

In the present study, we macroscopically examined the origin and insertion, distribution of intramuscular tendons and arrangement of muscle fibers in the lower leg muscles from the point of view of physical therapy. It should be noted that the arrangement of the muscle fibers is much more complicated than that described in ordinary textbooks of anatomy. Many of the lower leg muscles are composed of short muscle fibers that run in some portion unipennately and in other portion bipennately or radially. The arrangement of muscle fibers in each muscle is very important not only for functional assessment but also for muscle stretching in the physical therapy. It is clear that not all muscle fibers can be enough stretched only by the indirect stretching through extension or flexion of the joints. In the lower leg muscles, each muscle fibers should be stretched by the direct stretching through compression and expansion according to the arrangement of muscle fibers. We should always keep in mind the distribution of the intramuscular tendons, because we should differentiate them from intramuscular induration during palpation of muscles.
References